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(54) **MULTI-LAYER GOLF BALL**

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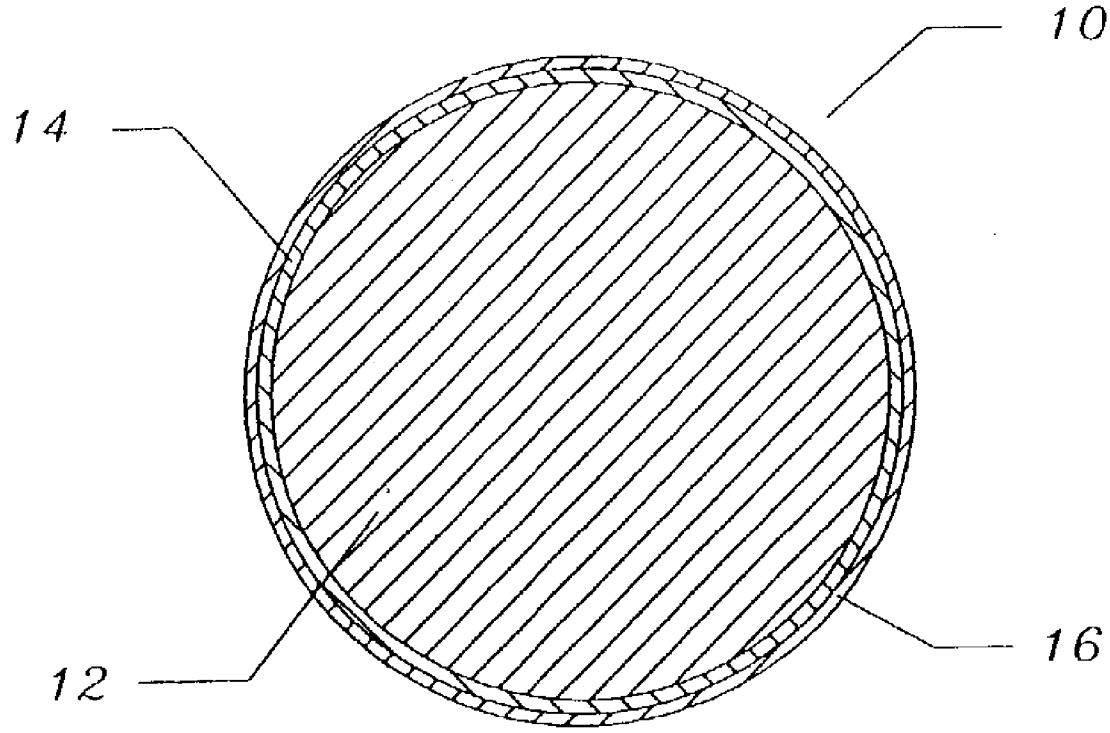
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(57) **ABSTRACT**

A golf ball including a solid core having an outer diameter of less than about 1.59 inches; an outer cover layer having a first material hardness and including a urethane elastomer formed from a castable reactive liquid material; and a casing disposed between the core and the cover layer, the casing including polyurea and having an outer diameter of between about 1.59 inches and about 1.64 inches and a second material hardness of between about 30 and about 70 Shore D; wherein a ratio of the second material hardness to the first material hardness is greater than 1.5.



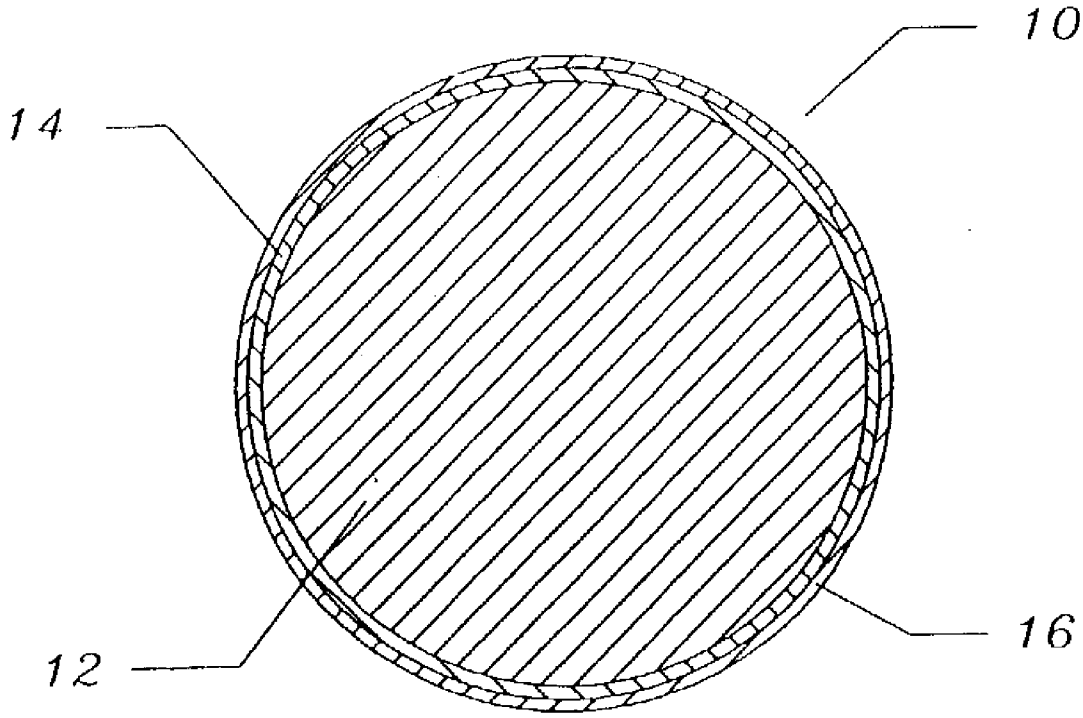


Fig. 1

MULTI-LAYER GOLF BALL

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This Application is a Divisional of co-pending U.S. application Ser. No. 09/832,142, filed Mar. 14, 2001.

FIELD OF THE INVENTION

[0002] This invention relates generally to golf balls, and more specifically, to multilayer golf balls. In particular, this invention relates to a golf ball having a core and a cover comprising a thin inner cover layer (a "casing") and a soft, thin, outer cover layer.

BACKGROUND OF THE INVENTION

[0003] There are a variety of different types of golf ball constructions, the majority of which, however, fall into two general categories: solid and wound golf balls. Solid golf balls include one-piece, two-piece, and multi-layer golf balls. One-piece golf balls are inexpensive and easy to construct, but have poor playing characteristics and are, therefore, usually limited for use as range balls. Two-piece balls are generally constructed with a polybutadiene solid core and a cover and are typically the most popular with recreational golfers because they are very durable and provide good distance. These balls are also relatively inexpensive and easy to manufacture, but are regarded by top players as having limited playing characteristics. Multi-layer golf balls are comprised of a solid core and a cover, either of which may be formed of one or more layers. These balls are regarded as having an extended range of playing characteristics, but are more expensive and difficult to manufacture than are one- and two-piece golf balls.

[0004] Wound golf balls, which typically include a fluid-filled center surrounded by tensioned elastomeric material and a cover, generally provide higher spin and soft "feel" characteristics but are more difficult and expensive to manufacture than are one-piece, two-piece, and multi-layer golf balls. Manufacturers are, therefore, constantly striving to produce a solid ball that incorporates the beneficial characteristics of a wound construction.

[0005] A variety of golf balls have been designed by manufacturers to provide a wide range of playing characteristics, such as compression, velocity, "feel," and spin. These characteristics can be adjusted and optimized for a variety of playing abilities. For example, manufacturers can adjust these properties by altering the materials (i.e., polymer compositions) and/or the physical construction of each or all of the various golf ball components (i.e., centers, cores, intermediate layers, and covers). Polymers commonly employed by manufacturers for the construction of golf balls include polybutadiene (cores), ionomers, such as SURLYN, commercially available from DuPont (covers and intermediate layers), and polyurethanes (covers and intermediate layers). Finding the right combination of core and layer materials and construction to produce a golf ball suited for a predetermined set of performance criteria, in particular, increased resilience and, therefore, velocity, without a loss in "feel" is a task that is challenging.

[0006] It is desirable, therefore, to construct a ball having increased resilience formed of a soft, thin, urethane cover layer combined with a harder, thin ionomer casing, according to the present invention. This construction, coupled with a high-Mooney-viscosity polybutadiene core, also described by the present invention, has been found to raise the velocity of a golf ball prepared in this manner without detrimentally affecting desirable ball characteristics, such as spin, "feel," and resiliency.

SUMMARY OF THE INVENTION

[0007] The present invention is directed to a golf ball comprising a solid core, an outer cover layer, and a casing disposed between the core and the outer cover layer, wherein the core has an outer diameter of no greater than about 1.58 inches; the casing has an outer diameter of greater than 1.58 inches and a material hardness of between about 30 and about 70 Shore D; and the outer cover layer has a material hardness of less than about 45 Shore D.

[0008] In one embodiment, the outer cover layer material hardness is less than about 40 Shore D and, alternatively, the outer cover layer material hardness is between about 25 and about 40 Shore D. The casing material hardness is preferably between about 50 and about 65 Shore D and, further, at least one of the casing and the outer cover layer has a thickness of less than about 0.05 inches. It is preferred that at least one of the casing and the outer cover layer has a thickness of between about 0.02 inches and about 0.04 inches.

[0009] The casing outer diameter should be from about 1.58 inches to about 1.64 inches and preferably, from about 1.59 inches to about 1.63 inches. In another embodiment, the outer cover layer is formed of a polyurethane composition comprising the reaction product of at least one polyisocyanate, a polyol, and at least one curing agent.

[0010] In another embodiment, the ball has a moment of inertia of less than about 85 $g \cdot cm^2$ and, preferably, the ball has a moment of inertia of less than about 83 $g \cdot cm^2$. The core, alternatively, has a first hardness and the casing has a second hardness greater than the first and/or the outer cover layer has a third hardness less than the second hardness. The casing comprises ionic copolymers of ethylene and an unsaturated monocarboxylic acid; thermoplastic and thermoset resins; metallocenes; vinyl resins; polyolefins; polyurethanes; polyureas; polyamides; acrylic resins; thermoplastic polyesters; and mixtures thereof. In a preferred embodiment, the casing comprises comprises ionic copolymers of ethylene and an unsaturated monocarboxylic acid.

[0011] In still another embodiment, the casing material hardness is between about 40 and about 70 Shore D and the outer cover layer material hardness is less than about 40 Shore D. Alternatively, a ratio of the casing material hardness (Shore D) to the outer cover layer material hardness is greater than 1.5.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** is a cross-sectional view of a golf ball having a core and an inner and outer cover according to the present invention.

DEFINITIONS

[0013] The term "about," as used herein in connection with one or more numbers or numerical ranges, should be understood to refer to all such numbers, including all numbers in a range.

[0014] As used herein, "cis-to-trans catalyst" means any component or a combination thereof that will convert at least a portion of cis-polybutadiene isomer to trans-polybutadiene isomer at a given temperature. It should be understood that the combination of the cis-isomer, the trans-isomer, and any vinyl-isomer, measured at any given time, comprises 100 percent of the polybutadiene.

[0015] As used herein, the term "active ingredients" is defined as the specific components of a mixture or blend that are essential to the chemical reaction.

[0016] As used herein, substituted and unsubstituted "aryl" groups means a hydrocarbon ring bearing a system of conjugated double bonds, typically comprising $4n+2\pi$ ring electrons, where n is an integer. Examples of aryl groups include, but are not limited to phenyl, naphthyl, anisyl, tolyl, xylenyl and the like. According to the present invention, aryl also includes heteroaryl groups, e.g., pyrimidine or thiophene. These aryl groups may also be substituted with any number of a variety of functional groups. In addition to the functional groups described herein in connection with carbocyclic groups, functional groups on the aryl groups can include hydroxy and metal salts thereof; mercapto and metal salts thereof; halogen; amino, nitro, cyano, and amido; carboxyl including esters, acids, and metal salts thereof; silyl; acrylates and metal salts thereof; sulfonyl or sulfonamide; and phosphates and phosphites; and a combination thereof.

[0017] As used herein, the term "Atti compression" is defined as the deflection of an object or material relative to the deflection of a calibrated spring, as measured with an Atti Compression Gauge, that is commercially available from Atti Engineering Corp. of Union City, N.J. Atti compression is typically used to measure the compression of a golf ball. When the Atti Gauge is used to measure cores having a diameter of less than 1.680 inches, it should be understood that a metallic or other suitable shim is used to make the diameter of the measured object 1.680 inches.

[0018] As used herein, substituted and unsubstituted "carbocyclic" means cyclic carbon-containing compounds, including, but not limited to cyclopentyl, cyclohexyl, cycloheptyl, adamantyl, and the like. Such cyclic groups may also contain various substituents in which one or more hydrogen atoms has been replaced by a functional group. Such functional groups include those described above, and lower alkyl groups having from 1-28 carbon atoms. The cyclic groups of the invention may further comprise a heteroatom.

[0019] As used herein, the term "coefficient of restitution" for golf balls is defined as the ratio of the rebound velocity to the inbound velocity when balls are fired into a rigid plate with a mass of at least 50 lb. The inbound velocity is understood to be 125 ft/s.

[0020] As used herein, the terms "Group VIA component" or "Group VIA element" mean a component that includes a sulfur component, a selenium component, or a tellurium component, or a combination thereof.

[0021] As used herein, the term "sulfur component" means a component that is elemental sulfur, polymeric sulfur, or a combination thereof. It should be further understood that "elemental sulfur" refers to the ring structure of S8 and that "polymeric sulfur" is a structure including at least one additional sulfur relative to the elemental sulfur.

[0022] As used herein, the term "fluid" includes a liquid, a paste, a gel, a gas, or any combination thereof.

[0023] As used herein, the term "molecular weight" is defined as the absolute weight average molecular weight. The molecular weight is determined by the following method: approximately 20 mg of polymer is dissolved in 10 mL of tetrahydrofuran ("THF"), which may take a few days at room temperature depending on the polymer's molecular weight and distribution. One liter of THF is filtered and degassed before being placed in a high-performance liquid chromatography ("HPLC") reservoir. The flow rate of the HPLC is set to 1 mL/min through a Viscogel column. This non-shedding, mixed bed, column model GMHHR-H, which has an ID of 7.8 mm and 300 mm long is available from Viscotek Corp. of Houston, Tex. The THF flow rate is set to 1 mL/min for at least one hour before sample analysis is begun or until stable detector baselines are achieved. During this purging of the column and detector, the internal temperature of the Viscotek TDA Model 300 triple detector should be set to 40° C. This detector is also available from Viscotek Corp. The three detectors (i.e., Refractive Index, Differential Pressure, and Light Scattering) and the column should be brought to thermal equilibrium, and the detectors should be purged and zeroed, to prepare the system for calibration according to the instructions provided with this equipment. A 100-μL aliquot of sample solution can then be injected into the equipment and the molecular weight of each sample can be calculated with the Viscotek's triple detector software. When the molecular weight of the polybutadiene material is measured, a dn/dc of 0.130 should always be used. It should be understood that this equipment and these methods provide the molecular weight numbers described and claimed herein, and that other equipment or methods will not necessarily provide equivalent values as used herein.

[0024] As used herein, the term "multilayer" means at least two layers and includes liquid center balls, wound balls, hollow-center balls, and balls with at least two intermediate layers and/or an inner and an outer cover.

[0025] As used herein, the term "thermoset" material refers to an irreversible, solid polymer that is the product of the reaction of at least one polymer and at least one crosslinking agent.

[0026] As used herein, the term "parts per hundred," also known as "phr," is defined as the number of parts by weight of a particular component present in a mixture, relative to 100 parts by weight of the total polymer component. Mathematically, this can be expressed as the weight of an ingredient divided by the total weight of the polymer, multiplied by a factor of 100.

[0027] As used herein, the term "substantially free" means less than about 5 weight percent, preferably less than about 3 weight percent, more preferably less than about 1 weight percent, and most preferably less than about 0.01 weight percent.

[0028] As used herein the term "resilience index" is defined as the difference in loss tangent measured at 10 cpm and 1000 cpm divided by 990 (the frequency span) multiplied by 100,000 (for normalization and unit convenience). The loss tangent is measured using an RPA 2000 manufactured by Alpha Technologies of Akron, Ohio. The RPA 2000

is set to sweep from 2.5 to 1000 cpm at a temperature of 100° C. using an arc of 0.5 degrees. An average of six loss tangent measurements are acquired at each frequency and the average is used in calculation of the resilience index. The computation of resilience index is as follows:

Resilience Index=100,000·[(loss tangent@10 *cpm*)−(loss tangent@1000 *cpm*)]/990

DETAILED DESCRIPTION OF THE INVENTION

[**0029**] Referring to **FIG. 1, a** golf ball **10** of the present invention includes a core **12**, a casing **14** surrounding the core **12**, and an outer cover layer **16**. The golf ball cores of the present invention may comprise a variety of constructions. The core may be a single layer or may comprise a plurality of layers. The core may also comprise a solid center around which many yards of a tensioned elastomeric material are wound.

[**0030**] The materials for solid cores include compositions having a base rubber, a crosslinking agent, a filler, and a co-crosslinking or initiator agent. The base rubber typically includes natural or synthetic rubbers. A preferred base rubber is 1,4-polybutadiene having a cis-structure of at least 40%. Most preferably, the base rubber comprises high-Mooney-viscosity rubber. If desired, the polybutadiene can also be mixed with other elastomers known in the art such as natural rubber, polyisoprene rubber and/or styrene-butadiene rubber in order to modify the properties of the core.

[**0031**] The crosslinking agent includes a metal salt of an unsaturated fatty acid such as a zinc salt or a magnesium salt of an unsaturated fatty acid having 3 to 8 carbon atoms such as acrylic or methacrylic acid. Suitable cross linking agents include metal salt diacrylates, dimethacrylates and monomethacrylates wherein the metal is magnesium, calcium, zinc, aluminum, sodium, lithium or nickel.

[**0032**] The initiator agent can be any known polymerization initiator which decomposes during the cure cycle. Suitable initiators include peroxide compounds such as dicumyl peroxide, 1,1-di(t-butylperoxy) 3,3,5-trimethyl cyclohexane, a-a bis (t-butylperoxy) diisopropylbenzene, 2,5-dimethyl-2,5 di(t-butylperoxy) hexane or di-t-butyl peroxide and mixtures thereof.

[**0033**] As used herein, the term "filler" includes any compound or composition that can be used to vary the density and other properties of the core. Fillers typically include materials such as tungsten, zinc oxide, barium sulfate, silica, calcium carbonate, zinc carbonate, metals, metal oxides and salts, regrind (recycled core material typically ground to about 30 mesh particle), high-Mooney-viscosity rubber regrind, and the like.

[**0034**] The invention also includes a method to convert the cis-isomer of the polybutadiene resilient polymer component to the trans-isomer during a molding cycle and to form a golf ball. A variety of methods and materials have been disclosed in U.S. Pat. No. 6,162,135 and U.S. application Ser. No. 09/461,736, filed Dec. 16, 1999; Ser. No. 09/458,676, filed Dec. 10, 1999; and Ser. No. 09/461,421, filed Dec. 16, 1999, each of which are incorporated herein, in their entirety, by reference. Various combinations of polymers, cis-to-trans catalysts, fillers, crosslinkers, and a source of free radicals, may be used. To obtain a higher resilience and lower compression center or intermediate layer, a high-molecular weight polybutadiene with a cis-isomer content preferably greater than about 90 percent is converted to increase the percentage of trans-isomer content at any point in the golf ball or portion thereof, preferably to increase the percentage throughout substantially all of the golf ball or portion thereof, during the molding cycle. More preferably, the cis-polybutadiene isomer is present in an amount of greater than about 95 percent of the total polybutadiene content. Without wishing to be bound by any particular theory, it is believed that a low amount of 1,2-polybutadiene isomer ("vinyl-polybutadiene") is desired in the initial polybutadiene, and the reaction product. Preferably, the vinyl polybutadiene isomer content is less than about 7 percent. More preferably, the vinyl polybutadiene isomer content is less than about 4 percent. Most preferably, the vinyl polybutadiene isomer content is less than about 2 percent. Without wishing to be bound by any particular theory, it is also believed that the resulting mobility of the combined cis- and trans-polybutadiene backbone is responsible for the lower modulus and higher resilience of the reaction product and golf balls including the same.

[**0035**] Crosslinkers are included to increase the hardness of the reaction product. Suitable crosslinking agents include one or more metallic salts of unsaturated fatty acids or monocarboxylic acids, such as zinc, calcium, or magnesium acrylate salts, and the like, and mixtures thereof. Preferred acrylates include zinc acrylate, zinc diacrylate, zinc methacrylate, and zinc dimethacrylate, and mixtures thereof. The crosslinking agent must be present in an amount sufficient to crosslink a portion of the chains of polymers in the resilient polymer component. For example, the desired compression may be obtained by adjusting the amount of crosslinking. This may be achieved, for example, by altering the type and amount of crosslinking agent, a method well-known to those of ordinary skill in the art. The crosslinking agent is typically present in an amount greater than about 10 phr of the polymer component, preferably from about 10 to 40 phr of the polymer component, more preferably from about 10 to 30 phr of the polymer component. When an organosulfur is selected as the cis-to-trans catalyst, zinc diacrylate may be selected as the crosslinking agent and is present in an amount of less than about 40 phr.

[**0036**] Fillers added to one or more portions of the golf ball typically include processing aids or compounds to affect rheological and mixing properties, density-modifying fillers, tear strength, or reinforcement fillers, and the like. The fillers are generally inorganic, and suitable fillers include numerous metals or metal oxides, such as zinc oxide and tin oxide, as well as barium sulfate, zinc sulfate, calcium carbonate, barium carbonate, clay, tungsten, tungsten carbide, an array of silicas, and mixtures thereof. Fillers may also include various foaming agents or blowing agents which may be readily selected by one of ordinary skill in the art. Fillers may include polymeric, ceramic, metal, and glass microspheres may be solid or hollow, and filled or unfilled. Fillers are typically also added to one or more portions of the golf ball to modify the density thereof to conform to uniform golf ball standards. Fillers may also be used to modify the weight of the center or at least one additional layer for specialty balls, e.g., a lower weight ball is preferred for a player having a low swing speed.

[0037] The polymers, free-radical initiator, filler(s), and any other materials used in forming either the golf ball center or any portion of the core, in accordance with the invention, may be combined to form a mixture by any type of mixing known to one of ordinary skill in the art. Suitable types of mixing include single pass and multi-pass mixing, and the like. The crosslinking agent, and any other optional additives used to modify the characteristics of the golf ball center or additional layer(s), may similarly be combined by any type of mixing. A single-pass mixing process where ingredients are added sequentially is preferred, as this type of mixing tends to increase efficiency and reduce costs for the process. The preferred mixing cycle is single step wherein the polymer, cis-to-trans catalyst, filler, zinc diacrylate, and peroxide are added sequentially. Suitable mixing equipment is well known to those of ordinary skill in the art, and such equipment may include a Banbury mixer, a two-roll mill, or a twin screw extruder.

[0038] Conventional mixing speeds for combining polymers are typically used, although the speed must be high enough to impart substantially uniform dispersion of the constituents. On the other hand, the speed should not be too high, as high mixing speeds tend to break down the polymers being mixed and particularly may undesirably decrease the molecular weight of the polymer component. The speed should thus be low enough to avoid high shear, which may result in loss of desirably high molecular weight portions of the polymer component. Also, too high a mixing speed may undesirably result in creation of enough heat to initiate the during the mixing cycle. The mixing temperature depends upon the type of polymer components, and more importantly, on the type of free-radical initiator. For example, when using di(2-t-butyl-peroxyisopropyl)benzene as the free-radical initiator, a mixing temperature of about 80° C. to 125° C., preferably about 88° C. to 110° C., and more preferably about 90° C. to 100° C., is suitable to safely mix the ingredients. Additionally, it is important to maintain a mixing temperature below the peroxide decomposition temperature. For example, if dicumyl peroxide is selected as the peroxide, the temperature should not exceed 100° F. Suitable mixing speeds and temperatures are well-known to those of ordinary skill in the art, or may be readily determined without undue experimentation.

[0039] The mixture can be subjected to, e.g., a compression or injection molding process, to obtain solid spheres for the center or hemispherical shells for forming an intermediate layer. The polymer mixture is subjected to a molding cycle in which heat and pressure are applied while the mixture is confined within a mold. The cavity shape depends on the portion of the golf ball being formed. The heat liberates free radicals by decomposing one or more peroxides, which may initiate the cis-to-trans conversion and crosslinking simultaneously. The temperature and duration of the molding cycle are selected based upon reactivity of the mixture. The molding cycle may have a single step of molding the mixture at a single temperature for a fixed time duration. An example of a single step molding cycle, for a mixture that contains dicumyl peroxide, would hold the polymer mixture at 340° F. for a duration of 15 minutes. The molding cycle may also include a two-step process, in which the polymer mixture is held in the mold at an initial temperature for an initial duration of time, followed by holding at a second, typically higher temperature for a second duration of time. An example of a two-step molding cycle would be holding the mold at 290° F. for 40 minutes, then ramping the mold to 340° F. where it is held for a duration of 20 minutes. In a preferred embodiment of the current invention, a single-step cure cycle is employed. Single-step processes are effective and efficient, reducing the time and cost of a two-step process. The polybutadiene, cis-to-trans conversion catalyst, additional polymers, free-radical initiator, filler, and any other materials used in forming either the golf ball center or any portion of the core, in accordance with the invention, may be combined to form a golf ball by an injection molding process, which is also well-known to one of ordinary skill in the art. Although the curing time depends on the various materials selected, a particularly suitable curing time is about 5 to 18 minutes, preferably from about 8 to 15 minutes, and more preferably from about 10 to 12 minutes. Those of ordinary skill in the art will be readily able to adjust the curing time upward or downward based on the particular materials used and the discussion herein.

[0040] The crosslinked or cured polymer component, which contains a greater amount of trans-polybutadiene than the uncured polymer component, is formed into an article having a first hardness at a point in the interior and a surface having a second hardness such that the second hardness differs from the first hardness by greater than 10 percent of the first hardness. Preferably, the article is a sphere and the first point is the midpoint of the article. In another embodiment, the second hardness differs from the first by greater than 20 percent of the first hardness. The cured article also has a first amount of trans-polybutadiene at an interior location and a second amount of trans-polybutadiene at a surface location, wherein the first amount is at least about 6 percent less than the second amount, preferably at least about 10 percent less than the second amount, and more preferably at least about 20 percent less than the second amount. The interior location is preferably a midpoint and the article is preferably a sphere. In one embodiment, the compression of the core, or portion of the core, of golf balls prepared according to the invention is preferably below about 50, more preferably below about 25.

[0041] The cover provides the interface between the ball and a club. Properties that are desirable for the cover include good moldability, high abrasion resistance, high tear strength, high resilience, and good mold release. The cover typically has a thickness to provide sufficient strength, good performance characteristics, and durability. The cover preferably has a thickness of less than about 0.1 inches, more preferably, less than about 0.05 inches, and most preferably, between about 0.02 inches and about 0.04 inches. The invention is particularly directed towards a multilayer golf ball which comprises a core, a casing, and an outer cover layer. In this embodiment, preferably, at least one of the casing and outer cover layer has a thickness of less than about 0.05 inches, more preferably between about 0.02 inches and about 0.04 inches. Most preferably, the thickness of either layer is about 0.03 inches.

[0042] When the golf ball of the present invention includes a casing, this layer can include any materials known to those of ordinary skill in the art, including thermoplastic and thermosetting material, but preferably the casing can include any suitable materials, such as ionic copolymers of ethylene and an unsaturated monocarboxylic acid which are available under the trademark SURLYN of E. I. DuPont de

Nemours & Co., of Wilmington, Del., or IOTEK or ESCOR of Exxon. These are copolymers or terpolymers of ethylene and methacrylic acid or acrylic acid partially neutralized with salts of zinc, sodium, lithium, magnesium, potassium, calcium, manganese, nickel or the like, in which the salts are the reaction product of an olefin having from 2 to 8 carbon atoms and an unsaturated monocarboxylic acid having 3 to 8 carbon atoms. The carboxylic acid groups of the copolymer may be totally or partially neutralized and might include methacrylic, crotonic, maleic, fumaric or itaconic acid.

[0043] This golf ball can likewise include one or more homopolymeric or copolymeric casing materials, such as:

[0044] (1) Vinyl resins, such as those formed by the polymerization of vinyl chloride, or by the copolymerization of vinyl chloride with vinyl acetate, acrylic esters or vinylidene chloride;

[0045] (2) Polyolefins, such as polyethylene, polypropylene, polybutylene and copolymers such as ethylene methylacrylate, ethylene ethylacrylate, ethylene vinyl acetate, ethylene methacrylic or ethylene acrylic acid or propylene acrylic acid and copolymers and homopolymers produced using a single-site catalyst or a metallocene catalyst;

[0046] (3) Polyurethanes, such as those prepared from polyols and diisocyanates or polyisocyanates and those disclosed in U.S. Pat. No. 5,334,673;

[0047] (4) Polyureas, such as those disclosed in U.S. Pat. No. 5,484,870;

[0048] (5) Polyamides, such as poly(hexamethylene adipamide) and others prepared from diamines and dibasic acids, as well as those from amino acids such as poly(caprolactam), and blends of polyamides with SURLYN, polyethylene, ethylene copolymers, ethylpropylene-non-conjugated diene terpolymer, and the like;

[0049] (6) Acrylic resins and blends of these resins with poly vinyl chloride, elastomers, and the like;

[0050] (7) Thermoplastics, such as urethanes; olefinic thermoplastic rubbers, such as blends of polyolefins with ethylene-propylene-non-conjugated diene terpolymer; block copolymers of styrene and butadiene, isoprene or ethylene-butylene rubber; or copoly-(ether-amide), such as PEBAX, sold by ELF Atochem of Philadelphia, Pa.;

[0051] (8) Polyphenylene oxide resins or blends of polyphenylene oxide with high impact polystyrene as sold under the trademark NORYL by General Electric Company of Pittsfield, Mass.;

[0052] (9) Thermoplastic polyesters, such as polyethylene terephthalate, polybutylene terephthalate, polyethylene terephthalate/glycol modified and elastomers sold under the trademarks HYTREL by E. I. DuPont de Nemours & Co. of Wilmington, Del., and LOMOD by General Electric Company of Pittsfield, Mass.;

[0053] (10) Blends and alloys, including polycarbonate with acrylonitrile butadiene styrene, polybutylene terephthalate, polyethylene terephthalate, styrene maleic anhydride, polyethylene, elastomers, and the like, and polyvinyl chloride with acrylonitrile butadiene styrene or ethylene vinyl acetate or other elastomers; and

[0054] (11) Blends of thermoplastic rubbers with polyethylene, propylene, polyacetal, nylon, polyesters, cellulose esters, and the like.

[0055] Preferably, the casing includes polymers, such as ethylene, propylene, butene-1 or hexane-1 based homopolymers or copolymers including functional monomers, such as acrylic and methacrylic acid and fully or partially neutralized ionomer resins and their blends, methyl acrylate, methyl methacrylate homopolymers and copolymers, imidized, amino group containing polymers, polycarbonate, reinforced polyamides, polyphenylene oxide, high impact polystyrene, polyether ketone, polysulfone, poly(phenylene sulfide), acrylonitrile-butadiene, acrylic-styrene-acrylonitrile, poly(ethylene terephthalate), poly(butylene terephthalate), poly(ethelyne vinyl alcohol), poly(tetrafluoroethylene) and their copolymers including functional comonomers, and blends thereof. Suitable cover compositions also include a polyether or polyester thermoplastic urethane, a thermoset polyurethane, a low modulus ionomer, such as acid-containing ethylene copolymer ionomers, including E/X/Y terpolymers where E is ethylene, X is an acrylate or methacrylate-based softening comonomer present in about 0 to 50 weight percent and Y is acrylic or methacrylic acid present in about 5 to 35 weight percent. More preferably, in a low spin rate embodiment designed for maximum distance, the acrylic or methacrylic acid is present in about 16 to 35 weight percent, making the ionomer a high modulus ionomer. In a higher spin embodiment, the inner cover layer includes an ionomer where an acid is present in about 10 to 15 weight percent and includes a softening comonomer.

[0056] The cover preferably includes a polyurethane composition comprising the reaction product of at least one polyisocyanate, polyol, and at least one curing agent. Any polyisocyanate available to one of ordinary skill in the art is suitable for use according to the invention. Exemplary polyisocyanates include, but are not limited to, 4,4'-diphenylmethane diisocyanate ("MDI"); polymeric MDI; carbodiimide-modified liquid MDI; 4,4'-dicyclohexylmethane diisocyanate ("H_{12}MDI"); p-phenylene diisocyanate ("PPDI"); m-phenylene diisocyanate ("MPDI"); toluene diisocyanate ("TDI"); 3,3'-dimethyl-4,4'-biphenylene diisocyanate ("TODI"); isophoronediisocyanate ("IPDI"); hexamethylene diisocyanate ("HDI"); naphthalene diisocyanate ("NDI"); xylene diisocyanate ("XDI"); p-tetramethylxylene diisocyanate ("p-TMXDI"); m-tetramethylxylene diisocyanate ("m-TMXDI"); ethylene diisocyanate; propylene-1,2-diisocyanate; tetramethylene-1,4-diisocyanate; cyclohexyl diisocyanate; 1,6-hexamethylene-diisocyanate ("HDI"); dodecane-1,12-diisocyanate; cyclobutane-1,3-diisocyanate; cyclohexane-1,3-diisocyanate; cyclohexane-1,4-diisocyanate; 1-isocyanato-3,3,5-trimethyl-5-isocyanatomethylcyclohexane; methyl cyclohexylene diisocyanate; triisocyanate of HDI; triisocyanate of 2,4,4-trimethyl-1,6-hexane diisocyanate ("TMDI"); tetracene diisocyanate; napthalene diisocyanate; anthracene diisocyanate; isocyanurate of toluene diisocyanate; uretdione of hexamethylene diisocyanate; and mixtures thereof. Polyisocyanates are known to those of ordinary skill in the art as having more than one isocyanate group, e.g., di-isocyanate, tri-isocyanate, and tetra-isocyanate. Preferably, the polyisocyanate includes MDI, PPDI,

TDI, or a mixture thereof, and more preferably, the polyisocyanate includes MDI. It should be understood that, as used herein, the term "MDI" includes 4,4'-diphenylmethane diisocyanate, polymeric MDI, carbodiimide-modified liquid MDI, and mixtures thereof and, additionally, that the diisocyanate employed may be "low free monomer," understood by one of ordinary skill in the art to have lower levels of "free" monomer isocyanate groups, typically less than about 0.1% free monomer groups. Examples of "low free monomer" diisocyanates include, but are not limited to Low Free Monomer MDI, Low Free Monomer TDI, and Low Free Monomer PPDI.

[0057] The at least one polyisocyanate should have less than about 14% unreacted NCO groups. Preferably, the at least one polyisocyanate has no greater than about 7.5% NCO, and more preferably, less than about 7.0%.

[0058] Any polyol available to one of ordinary skill in the art is suitable for use according to the invention. Exemplary polyols include, but are not limited to, polyether polyols, hydroxy-terminated polybutadiene (including partially/fully hydrogenated derivatives), polyester polyols, polycaprolactone polyols, and polycarbonate polyols. In one preferred embodiment, the polyol includes polyether polyol. Examples include, but are not limited to, polytetramethylene ether glycol ("PTMEG"), polyethylene propylene glycol, polyoxypropylene glycol, and mixtures thereof. The hydrocarbon chain can have saturated or unsaturated bonds and substituted or unsubstituted aromatic and cyclic groups. Preferably, the polyol of the present invention includes PTMEG.

[0059] In another embodiment, polyester polyols are included in the polyurethane material of the invention. Suitable polyester polyols include, but are not limited to, polyethylene adipate glycol; polybutylene adipate glycol; polyethylene propylene adipate glycol; o-phthalate-1,6-hexanediol; poly(hexamethylene adipate) glycol; and mixtures thereof. The hydrocarbon chain can have saturated or unsaturated bonds, or substituted or unsubstituted aromatic and cyclic groups.

[0060] In another embodiment, polycaprolactone polyols are included in the materials of the invention. Suitable polycaprolactone polyols include, but are not limited to, 1,6-hexanediol-initiated polycaprolactone, diethylene glycol initiated polycaprolactone, trimethylol propane initiated polycaprolactone, neopentyl glycol initiated polycaprolactone, 1,4-butanediol-initiated polycaprolactone, and mixtures thereof. The hydrocarbon chain can have saturated or unsaturated bonds, or substituted or unsubstituted aromatic and cyclic groups.

[0061] In yet another embodiment, the polycarbonate polyols are included in the polyurethane material of the invention. Suitable polycarbonates include, but are not limited to, polyphthalate carbonate and poly(hexamethylene carbonate) glycol. The hydrocarbon chain can have saturated or unsaturated bonds, or substituted or unsubstituted aromatic and cyclic groups. In one embodiment, the molecular weight of the polyol is from about 200 to about 4000.

[0062] Polyamine curatives are also suitable for use in the polyurethane composition of the invention and have been found to improve cut, shear, and impact resistance of the resultant balls. Preferred polyamine curatives include, but are not limited to, 3,5-dimethylthio-2,4-toluenediamine and isomers thereof; 3,5-diethyltoluene-2,4-diamine and isomers thereof, such as 3,5-diethyltoluene-2,6-diamine; 4,4'-bis-(sec-butylamino)-diphenylmethane; 1,4-bis-(sec-butylamino)-benzene, 4,4'-methylene-bis-(2-chloroaniline); 4,4'-methylene-bis-(3-chloro-2,6-diethylaniline) ("MCDEA"); polytetramethyleneoxide-di-p-aminobenzoate; N,N'-dialkyldiamino diphenyl methane; p,p'-methylene dianiline ("MDA"); m-phenylenediamine ("MPDA"); 4,4'-methylene-bis-(2-chloroaniline) ("MOCA"); 4,4'-methylene-bis-(2,6-diethylaniline) ("MDEA"); 4,4'-methylene-bis-(2,3-dichloroaniline) ("MDCA"); 4,4'-diamino-3,3'-diethyl-5,5'-dimethyl diphenylmethane; 2,2', 3,3'-tetrachloro diamino diphenylmethane; trimethylene glycol di-p-aminobenzoate; and mixtures thereof. Preferably, the curing agent of the present invention includes 3,5-dimethylthio-2,4-toluenediamine and isomers thereof, such as ETHACURE 300, commercially available from Albermarle Corporation of Baton Rouge, La. Suitable polyamine curatives, which include both primary and secondary amines, preferably have molecular weights ranging from about 64 to about 2000.

[0063] At least one of a diol, triol, tetraol, or hydroxy-terminated curatives may be added to the aforementioned polyurethane composition. Suitable diol, triol, and tetraol groups include ethylene glycol; diethylene glycol; polyethylene glycol; propylene glycol; polypropylene glycol; lower molecular weight polytetramethylene ether glycol; 1,3-bis(2-hydroxyethoxy) benzene; 1,3-bis-[2-(2-hydroxyethoxy) ethoxy] benzene; 1,3-bis-{2-[2-(2-hydroxyethoxy) ethoxy] ethoxy} benzene; 1,4-butanediol; 1,5-pentanediol; 1,6-hexanediol; resorcinol-di-(β-hydroxyethyl) ether; hydroquinone-di-(β-hydroxyethyl) ether; and mixtures thereof. Preferred hydroxy-terminated curatives include 1,3-bis(2-hydroxyethoxy) benzene; 1,3-bis-[2-(2-hydroxyethoxy) ethoxy] benzene; 1,3-bis-{2-[2-(2-hydroxyethoxy) ethoxy] ethoxy} benzene; 1,4-butanediol, and mixtures thereof. Preferably, the hydroxy-terminated curatives have molecular weights ranging from about 48 to 2000. It should be understood that molecular weight, as used herein, is the absolute weight average molecular weight and would be understood as such by one of ordinary skill in the art.

[0064] Both the hydroxy-terminated and amine curatives can include one or more saturated, unsaturated, aromatic, and cyclic groups. Additionally, the hydroxy-terminated and amine curatives can include one or more halogen groups. The polyurethane composition can be formed with a blend or mixture of curing agents. If desired, however, the polyurethane composition may be formed with a single curing agent.

[0065] Any method known to one of ordinary skill in the art may be used to combine the polyisocyanate, polyol, and curing agent of the present invention. One commonly employed method, known in the art as a one-shot method, involves concurrent mixing of the polyisocyanate, polyol, and curing agent. This method results in a mixture that is inhomogenous (more random) and affords the manufacturer less control over the molecular structure of the resultant composition. A preferred method of mixing is known as a prepolymer method. In this method, the polyisocyanate and the polyol are mixed separately prior to addition of the curing agent. This method affords a more homogeneous mixture resulting in a more consistent polymer composition. Other methods suitable for forming the layers of the present

invention include reaction injection molding ("RIM"), liquid injection molding ("LIM"), and pre-reacting the components to form an injection moldable thermoplastic polyurethane and then injection molding, all of which are known to one of ordinary skill in the art.

[0066] An optional filler component may be chosen to impart additional density to blends of the previously described components. The selection of such filler(s) is dependent upon the type of golf ball desired (i.e., one-piece, two-piece multi-component, or wound). Examples of useful fillers include zinc oxide, barium sulfate, calcium oxide, calcium carbonate and silica, as well as the other well known corresponding salts and oxides thereof. Additives, such as nanoparticles, glass spheres, and various metals, such as titanium and tungsten, can be added to the polyurethane compositions of the present invention, in amounts as needed, for their well-known purposes. Additional components which can be added to the polyurethane composition include UV stabilizers and other dyes, as well as optical brighteners and fluorescent pigments and dyes. Such additional ingredients may be added in any amounts that will achieve their desired purpose.

[0067] It has been found by the present invention that the use of a castable, reactive material, which is applied in a fluid form, makes it possible to obtain very thin outer cover layers on golf balls. Specifically, it has been found that castable, reactive liquids, which react to form a urethane elastomer material, provide desirable very thin outer cover layers.

[0068] The castable, reactive liquid employed to form the urethane elastomer material can be applied over the core using a variety of application techniques such as spraying, dipping, spin coating, or flow coating methods which are well known in the art. An example of a suitable coating technique is that which is disclosed in U.S. Pat. No. 5,733,428, filed May 2, 1995 entitled "Method And Apparatus For Forming Polyurethane Cover On A Golf Ball," the disclosure of which is hereby incorporated by reference in its entirety in the present application.

[0069] The cover is preferably formed around the casing by mixing and introducing the material in the mold halves. It is important that the viscosity be measured over time, so that the subsequent steps of filling each mold half, introducing the core into one half and closing the mold can be properly timed for accomplishing centering of the core cover halves fusion and achieving overall uniformity. Suitable viscosity range of the curing urethane mix for introducing cores into the mold halves is determined to be approximately between about 2,000 cP and about 30,000 cP, with the preferred range of about 8,000 cP to about 15,000 cP.

[0070] To start the cover formation, mixing of the prepolymer and curative is accomplished in motorized mixer including mixing head by feeding through lines metered amounts of curative and prepolymer. Top preheated mold halves are filled and placed in fixture units using centering pins moving into holes in each mold. At a later time, a bottom mold half or a series of bottom mold halves have similar mixture amounts introduced into the cavity. After the reacting materials have resided in top mold halves for about 40 to about 80 seconds, a core is lowered at a controlled speed into the gelling reacting mixture.

[0071] A ball cup holds the ball core through reduced pressure (or partial vacuum). Upon location of the coated core in the halves of the mold after gelling for about 40 to about 80 seconds, the vacuum is released allowing core to be released. The mold halves, with core and solidified cover half thereon, are removed from the centering fixture unit, inverted and mated with other mold halves which, at an appropriate time earlier, have had a selected quantity of reacting polyurethane prepolymer and curing agent introduced therein to commence gelling.

[0072] Similarly, U.S. Pat. No. 5,006,297 to Brown et al. and U.S. Pat. No. 5,334,673 to Wu both also disclose suitable molding techniques which may be utilized to apply the castable reactive liquids employed in the present invention. Further, U.S. Pat. Nos. 6,180,040 and 6,180,722 disclose methods of preparing dual core golf balls. The disclosures of these patents are hereby incorporated by reference in their entirety. However, the method of the invention is not limited to the use of these techniques.

[0073] Depending on the desired properties, balls prepared according to the invention can exhibit substantially the same or higher resilience, or coefficient of restitution ("COR"), with a decrease in compression or modulus, compared to balls of conventional construction. Additionally, balls prepared according to the invention can also exhibit substantially higher resilience, or COR, without an increase in compression, compared to balls of conventional construction. Another measure of this resilience is the "loss tangent," or tan 6, which is obtained when measuring the dynamic stiffness of an object. Loss tangent and terminology relating to such dynamic properties is typically described according to ASTM D4092-90. Thus, a lower loss tangent indicates a higher resiliency, thereby indicating a higher rebound capacity. Low loss tangent indicates that most of the energy imparted to a golf ball from the club is converted to dynamic energy, i.e., launch velocity and resulting longer distance. The rigidity or compressive stiffness of a golf ball may be measured, for example, by the dynamic stiffness. A higher dynamic stiffness indicates a higher compressive stiffness. To produce golf balls having a desirable compressive stiffness, the dynamic stiffness of the crosslinked reaction product material should be less than about 50,000 N/m at −50° C. Preferably, the dynamic stiffness should be between about 10,000 and 40,000 N/m at −50° C., more preferably, the dynamic stiffness should be between about 20,000 and 30,000 N/m at −50° C.

[0074] The molding process and composition of golf ball portions typically results in a gradient of material properties. Methods employed in the prior art generally exploit hardness to quantify these gradients. Hardness is a qualitative measure of static modulus and does not represent the modulus of the material at the deformation rates associated with golf ball use, i.e., impact by a club. As is well known to one skilled in the art of polymer science, the time-temperature superposition principle may be used to emulate alternative deformation rates. For golf ball portions including polybutadiene, a 1-Hz oscillation at temperatures between 0° C. and −50° C. are believed to be qualitatively equivalent to golf ball impact rates. Therefore, measurement of loss tangent and dynamic stiffness at 0° C. to −50° C. may be used to accurately anticipate golf ball performance, preferably at temperatures between about −20° C. and −50° C.

[0075] The resultant golf balls typically have a coefficient of restitution of greater than about 0.7, preferably greater

than about 0.75, and more preferably greater than about 0.78. The golf balls also typically have an Atti compression of at least about 40, preferably from about 50 to 120, and more preferably from about 60 to 100. The golf ball cured polybutadiene material typically has a hardness of at least about 15 Shore A, preferably between about 30 Shore A and 80 Shore D, more preferably between about 50 Shore A and 60 Shore D.

[0076] The core composition should comprise at least one rubber material having a resilience index of at least about 40. Preferably the resilience index is at least about 50. Polymers that produce resilient golf balls and, therefore, are suitable for the present invention, include but are not limited to CB23, CB22, commercially available from of Bayer Corp. of Orange, Tex., BR60, commercially available from Enichem of Italy, and 1207G, commercially available from Goodyear Corp. of Akron, Ohio. To clarify the method of computation for resilience index, the resilience index for CB23, for example, is computed as follows:

Resilience Index for *CB*23=100,000·[(0.954)−(0.407)]/990

[0077] Resilience Index for CB23=55

[0078] Additionally, the unvulcanized rubber, such as polybutadiene, in golf balls prepared according to the invention typically has a Mooney viscosity of between about 40 and about 80, more preferably, between about 45 and about 65, and most preferably, between about 45 and about 55. Mooney viscosity is typically measured according to ASTM-D1646.

[0079] When golf balls are prepared according to the invention, they typically will have dimple coverage greater than about 60 percent, preferably greater than about 65 percent, and more preferably greater than about 75 percent. The flexural modulus of the cover on the golf balls, as measured by ASTM method D6272-98, Procedure B, is typically greater than about 500 psi, and is preferably from about 500 psi to 150,000 psi. As discussed herein, the outer cover layer is preferably formed from a relatively soft polyurethane material. In particular, the material of the outer cover layer should have a material hardness, as measured by ASTM-D2240, less than about 45 Shore D, preferably less than about 40 Shore D, more preferably between about 25 and about 40 Shore D, and most preferably between about 30 and about 40 Shore D. The casing preferably has a material hardness of less than about 70 Shore D, more preferably between about 30 and about 70 Shore D, and most preferably, between about 50 and about 65 Shore D.

[0080] In a preferred embodiment, the casing material hardness is between about 40 and about 70 Shore D and the outer cover layer material hardness is less than about 40 Shore D. In a more preferred embodiment, a ratio of the casing material hardness to the outer cover layer material hardness is greater than 1.5.

[0081] It should be understood, especially to one of ordinary skill in the art, that there is a fundamental difference between "material hardness" and "hardness, as measured directly on a golf ball." Material hardness is defined by the procedure set forth in ASTM-D2240 and generally involves measuring the hardness of a flat "slab" or "button" formed of the material of which the hardness is to be measured. Hardness, when measured directly on a golf ball (or other spherical surface) is a completely different measurement and, therefore, results in a different hardness value. This difference results from a number of factors including, but not limited to, ball construction (i.e., core type, number of core and/or cover layers, etc.), ball (or sphere) diameter, and the material composition of adjacent layers. It should also be understood that the two measurement techniques are not linearly related and, therefore, one hardness value cannot easily be correlated to the other.

[0082] The core of the present invention has an Atti compression of between about 50 and about 90, more preferably, between about 60 and about 85, and most preferably, between about 65 and about 85. The overall outer diameter ("OD") of the core is less than about 1.590 inches, preferably, no greater than 1.580 inches, more preferably between about 1.540 inches and about 1.580 inches, and most preferably between about 1.525 inches to about 1.570 inches. The OD of the casing of the golf balls of the present invention is preferably between 1.580 inches and about 1.640 inches, more preferably between about 1.590 inches to about 1.630 inches, and most preferably between about 1.600 inches to about 1.630 inches.

[0083] The present multilayer golf ball can have an overall diameter of any size. Although the United States Golf Association ("USGA") specifications limit the minimum size of a competition golf ball to 1.680 inches. There is no specification as to the maximum diameter. Golf balls of any size, however, can be used for recreational play. The preferred diameter of the present golf balls is from about 1.680 inches to about 1.800 inches. The more preferred diameter is from about 1.680 inches to about 1.760 inches. The most preferred diameter is about 1.680 inches to about 1.740 inches.

[0084] The golf balls of the present invention should have a moment of inertia ("MOI") of less than about 85 and, preferably, less than about 83. The MOI is typically measured on model number MOI-005-104 Moment of Inertia Instrument manufactured by Inertia Dynamics of Collinsville, Conn. The instrument is plugged into a PC for communication via a COMM port and is driven by MOI Instrument Software version #1.2.

EXAMPLE

[0085] Golf balls were prepared, both according to the present invention and conventional technology, and are formed of a solid core having a diameter of 1.550 inches, a casing having a thickness of 0.035 inches, and an outer cover layer having a thickness of 0.030 inches, to provide a golf ball outer diameter of 1.68 inches. Two examples of golf balls according to the present invention were prepared, each having a different cover hardness. Example I, having a cover material hardness of 38 Shore D, and Example II, having a cover material hardness of 30 Shore D, are presented below in Table I. The outer cover of the Control golf ball, prepared according to conventional technology, comprises a PMS1088 prepolymer, commercially available from Polyurethane Specialties Co. (77.8%) cured with Ethacure 300, commercially available from Albemarle Corp. (18.7%), and white dispersion, commercially available from Harwich Chemical (3.5%).

TABLE I

	Control	Example I	Example II
Composition			
MDI/PTMEG 2000 prepolymer	—	6.0% NCO	6.0% NCO
PMS1088 prepolymer	6.0% NCO		
Versalink P-250[1]	—	0.270 eq.	0.550 eq.
Versalink P-650[2]	—	—	—
Ethacure 300[3]	0.95 eq.	0.680 eq.	0.400 eq.
HCC-19584 White Dispersion[4]	3.5%	3.5%	3.5%
Dabco-33LV Catalyst[5]	—	—	0.100%
Properties			
Material hardness (Shore D)	45	38	30

[1,2]Versalink P-250 and P-650 are oligomeric aromatic diamines manufactured by Air Products and Chemicals, Inc.
[3]Ethacure 300 is a liquid aromatic diamine manufactured by Albemarle Corporation.
[4]HCC-19584 White Dispersion is a colorant manufactured by Harwick Chemical Manufacturing Corporation.
[5]Dabco-33LV Catalyst is a solution of 33% triethylenediamine and 67% dipropylene glycol. It is manufactured by Air Products and Chemicals, Inc.

[0086] The casing layer for Examples I and II, and for the Control ball, were formed of a 50/50 Na/Li blend of SURLYN® 8945 and SURLYN® 7940.

[0087] Examples I and II were tested for a variety of golf ball properties, such as core compression, cover hardness, ball compression, ball velocity, ball moment of inertia, ball COR, and driver, 8-iron, ½-wedge, and full wedge spin, and compared to the Control ball, also tested for the same properties. The results for Examples I and II, and the Control ball, are presented below in Table II.

TABLE II

Ball Properties	Control	Example I	Example II
Core compression (Atti)	73	76	86
Core diameter (inches)	1.550	1.550	1.550
Casing thickness (inches)	0.035	0.035	0.035
Casing diameter (inches)	1.620	1.620	1.620
Casing material	Na/Li blend	Na/Li blend	Na/Li blend
Cover hardness (Shore D)			
material	45	30	38
on ball	55	54	54
Ball compression (Atti)	85	84	91
Ball velocity (ft/s)	253.2	254.6	255.1
Ball Moment of Inertia ($g \cdot cm^2$)	81.1	81.4	—
Ball COR	0.808	0.816	0.822
Spin			
Standard Driver spin (rpm)	3370	3460	3580
8-iron spin (rpm)	7430	7780	7930
½-wedge spin (rpm)	6930	7040	7200
full-wedge spin (rpm)	9400	9620	9840

[0088] It is clear from the data presented in Table II, that the golf balls of the present invention have increased 8-iron spin, ½-wedge, and full wedge, all of which are important to making approach shots stop at desired locations on the green, especially to those golfers whose launch conditions require a ball having higher iron spin.

[0089] The invention described and claimed herein is not to be limited in scope by the specific embodiments herein disclosed, since these embodiments are intended as illustrations of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

What is claimed is:

1. A golf ball comprising:

a solid core having an outer diameter of less than about 1.59 inches;

an outer cover layer having a first material hardness and comprising a elastomer formed from a castable reactive liquid material; and

a casing disposed between the core and the cover layer, the casing comprising polyurea and having an outer diameter of between about 1.59 inches and about 1.64 inches and a second material hardness of between about 30 and about 70 Shore D;

wherein a ratio of the second material hardness to the first material hardness is greater than 1.5.

2. The golf ball of claim 1, wherein the first material hardness is less than about 45 Shore D.

3. The golf ball of claim 2, wherein the first material hardness is between about 25 and about 40 Shore D.

4. The golf ball of claim 1, wherein the second material hardness is between about 50 and about 65 Shore D.

5. The golf ball of claim 1, wherein at least one of the casing and the outer cover layer has a thickness of less than about 0.05 inches.

6. The golf ball of claim 5, wherein at least one of the casing and the outer cover layer has a thickness of between about 0.02 inches and about 0.04 inches.

7. The golf ball of claim 1, wherein the core has a vinyl polybutadiene isomer content of less than about 7 percent.

8. The golf ball of claim 1, wherein the core comprises polybutadiene and a cis-to-trans catalyst such that, upon curing, the core has a first amount of trans-polybutadiene at an interior location and a second amount of trans-polybutadiene at a surface location, the first amount being at least about 6 percent less than the second amount.

9. The golf ball of claim 1, wherein the elastomer is a polyurethane composition comprising the reaction product of at least one polyisocyanate, a polyol, and at least one curing agent.

10. The golf ball of claim 1, wherein the core has a first hardness at a point in the interior and a surface having a second hardness differing from the first hardness by greater than 10 percent.

11. The golf ball of claim 1, wherein the core comprises a polybutadiene having a Mooney viscosity of between about 40 and about 80, a resilience index of at least about 50, or a dynamic stiffness of less than about 50,000 N/m at −50° C.

12. The golf ball of claim 1, wherein the golf ball has a dimple coverage of greater than about 75 percent.

13. The golf ball of claim 1, wherein the casing further comprises ionic copolymers of ethylene and an unsaturated monocarboxylic acid; vinyl resins; polyolefins; polyurethanes; polyamides; thermoplastic and thermoset resins; metallocenes; acrylic resins; or thermoplastic polyesters.

14. The golf ball of claim 1, wherein the casing material hardness is between about 40 and about 70 Shore D and the outer cover layer material hardness is less than about 40 Shore D.

15. The golf ball of claim 1, wherein at least one of the core, casing, and cover layer are cast, reaction injection molded, liquid injection molded, injection molded, or a mixture thereof.

16. A golf ball comprising:

a core having an outer diameter of less than about 1.59 inches and comprising a polybutadiene having a vinyl content of less than about 7 percent;

an outer cover layer having a first material hardness and formed from a polyurethane composition comprising the reaction product of at least one polyisocyanate, a polyol, and at least one curing agent; and

a casing disposed between the core and the cover layer, the casing comprising polyurea and having an outer diameter of between about 1.59 inches and about 1.64 inches and a second material hardness of between about 30 and about 70 Shore D;

wherein a ratio of the second material hardness to the first material hardness is greater than 1.5 and the golf ball has a moment of inertia of less than about 83 $g \cdot cm^2$.

17. The golf ball of claim 16, wherein at least one of the casing and the outer cover layer has a thickness of less than about 0.05 inches.

18. The golf ball of claim 16, wherein at least one of the casing and the outer cover layer has a thickness of between about 0.02 inches and about 0.04 inches.

19. The golf ball of claim 16, wherein the urethane elastomer is a polyurethane composition comprising the reaction product of at least one polyisocyanate, a polyol, and at least one curing agent.

20. The golf ball of claim 16, wherein at least one of the core, casing, and cover layer are cast, reaction injection molded, liquid injection molded, injection molded, or a mixture thereof.

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